Orenco SYSTEMS Technology Fact Sheet

Small Community Wastewater Treatment Facilities: Electrical Consumption Considerations

Background

Small rural communities in need of wastewater treatment facilities present a significant challenge to design engineers due to resource limitations, financial constraints, highly variable influent flows, and stringent discharge limits. As a result of these challenges, small communities have a limited history of construction and operation of wastewater facilities, and they currently account for the majority of violations to environmental regulation violations in the US.

Small communities have long struggled to provide wastewater solutions to their residents. Affordability is a huge barrier. The affordability, long-term performance, and compliance of a small wastewater treatment system demands a wastewater technology with reduced maintenance needs, little need for adjustment, low biosolids production, and low electrical consumption. Simple-to-operate, fixed film technologies are a good fit because they reduce the costs of operational inefficiencies and electricity.

Electricity constitutes between 25 to 40 percent of a typical wastewater treatment plant's operating budget (CGE, 2000). Consequently, electricity represents the greatest opportunity for cost reductions. Furthermore, with increasing energy costs and uncertainties about future fossil fuel supplies, the efficient management of energy is now of greater concern than ever before.

Water and wastewater facilities are typically among a community's largest energy consumers (California Energy Commission, 1990), accounting for 30 to 60% of municipal government energy usage (U.S. EPA, 2008) and 3 to 4% of the nation's total energy usage (WEF MOP No. 32, 2009). As populations grow and environmental requirements become more stringent, demand for electricity at water and wastewater facilities is expected to grow by approximately 20 percent over the next 15 years (Carns, 2005).

The electrical energy required for wastewater treatment varies widely but is typically between 1000 and 3000 kWh/MG for most treatment facilities (Wastewater Engineering, 2013). Electrical consumption is highly dependent upon the discharge permit requirements, secondary treatment system technology selected, and overall size of the WWTP. Three factors have the largest effect on energy intensity:

- **Wastewater Treatment Process.** The most common treatment process being used — suspended growth processes — have high energy requirements associated with delivering oxygen into the wastewater. By comparison, other technologies, such as fixed film processes, have substantially reduced energy requirements (NYSERDA, 2006).
- **Nutrient Removal.** Plants that have biological treatment for nutrient removal and filtration use about 30 to 50 percent more electricity for aeration, pumping, and solids-processing than conventional activated sludge treatment. Their electricity requirements will increase by 20% during the next 15 years as plants expand treatment capacity to meet population growth and as additional treatment parameters are applied to meet the rigorous mandates of the Safe Drinking Water Act and the Clean Water Act (EPRI, 1996).
- **Size of WWTP Facility.** Energy consumption (kWh/MG) in small wastewater treatment plants serving small communities (< 1 MGD) is often two or more times greater than it is in larger facilities (> 1 MGD). Energy consumption consumes 15 to 30% of the operation and maintenance (O&M) budgets at large WWTPs and 30 to 40% at small WWTPs (WEF MOP No. 32, 2009).

This document summarizes electrical consumption data for various wastewater treatment technologies and flows. The variability in the data is partially due to calculated versus measured and observed data, and complete WWTP data versus unit process data. In general, observed data is higher than theoretically calculated and derived energy intensity values.

Activated Sludge and Attached Growth Treatment Processes

Activated Sludge

Activated sludge treatment systems consist of a reactor in which the microorganisms responsible for treatment are kept in suspension and aerated. Proper mixing and aeration generally requires large amounts of oxygen that is typically supplied by larger horsepower blowers running continuously. According to Recommended Standards for Wastewater Facilities, "This process [activated sludge] requires close attention and competent operating supervision, including routine laboratory control. These requirements shall be considered when proposing this type of treatment. This process requires major energy usage to meet aeration demands. Energy costs and potential mandatory emergency public power reduction events in relation to critical water quality conditions must be carefully evaluated."

Attached Growth / Fixed Film

Alternatively, with attached growth systems, wastewater is uniformly distributed onto the media in an unsaturated condition. Air movement through the media's void space provides oxygen for aerobic digestion. The energy required for distributing the wastewater onto the media and aeration is considerably less than it is for activated sludge facilities. For example, AdvanTex Treatment Systems are a type of fixed film/attached growth treatment process designed specifically for small communities and small flow applications. AdvanTex Treatment Systems use fractional horsepower fans to draw air through the media to provide sufficient oxygen for aerobic digestion. Low Hp high-head turbine pumps operate intermittently with sophisticated controls that automatically adjust recirculation ratios and pump-run times based upon daily flows.

On average, AdvanTex systems provide a deduction relative to electrical usage of more than 50% compared to activated sludge facilities. AdvanTex treatment systems are specifically designed to minimize biosolids production and electrical usage associated with wastewater aeration.

Baseline Electric Energy Use Data

The following baseline energy intensity values are provided from the following: 1) energy audits or surveys conducted at complete wastewater treatment plants, and 2) theoretical or empirically derived values for discrete unit processes (primary clarification, SBR, trickling filter, secondary clarification, etc).

Water and Wastewater Energy Best Practices Guidebook (Science Applications International Corporation, 2006)

Focus on Energy, a utility-sponsored program to reduce energy in Wisconsin, retained a sub-consultant to conduct on-site surveys of 85 wastewater treatment facilities under 2006 operating conditions. The following chart shows actual energy use for each type of wastewater treatment plant.

Table 1. Energy Intensity Values for Various WWTPs (Science Applications International Corporation, 2006).

Treatment Type	Flow Range (MGD)	Number of Facilities Surveyed	kWh per Million Gallons
Activated Sludge	0 to 1	26	5440
	1 to 5	24	2503
	> 5	11	2288
Aerated Lagoon	0 to 1	15	7288
Oxidation Ditch	0 to 1.2	19	6895

Energy intensity values, with respect to small communities, ranged from an average of 5440 kWh/MG for activated sludge facilities, to an average of 7288 kWh/MG for Aerated Lagoon treatment plants. Small communities generally consumed two to three times the electricity compared to larger WWTPs. Fixed film technologies were not surveyed or evaluated as part of Focus on Energy's study.

Statewide Assessment of Energy Use By The Municipal Water and Wastewater Sector (New York State Energy Research and Development Authority [NYSERDA], 2008)

NYSERDA and its sub-consultant, Malcolm Pirnie, assessed the energy use by New York State's municipal water and wastewater facilities. Of the facilities surveyed, 174 participated, representing over 80 percent of the State's design treatment capacity. Energy intensity values for small communities (<1 MGD) are nearly three times higher than for wastewater treatment facilities greater than 1 MG.

Table 2. Energy Intensity Values for Various WWTPs (NYSERDA, 2008).

Category/Design Capacity	Energy Use (kWh/MG)
Less than 1 MGD	4620
1 to 5 MGD	1580
5 to 20 MGD	1740
20 to 75 MGD	1700
Greater than 75 MGD	1100

Electrical Use and Management in the Municipal Water Supply and Wastewater Industries (EPRI, 2013)

Published originally in 1996 and updated in 2013, The Electrical Power Research Institute (EPRI) studied electrical usage in water and wastewater treatment plant operations and processes throughout the US. As shown in Table 3, EPRI, again, recognizes the ability of fixed film processes (e.g. trickling filters) to treat wastewater with higher energy efficiency than conventional activated sludge processes.

The values provided in Table 3 are for the unit processes specified. Ancillary unit processes (primary clarification, secondary clarification, etc.) are excluded, which is why the values listed in Table 3 are considerably lower than those provided in the above tables.

Table 3. Energy Intensity Values (kWh/MG) for Various WWTP Unit Processes (EPRI, 2013).

Unit Process	Average Flow (MGD)					
	1	5	10	20	50	100
Trickling Filters (Fixed Film)	630	508	507	507	507	507
Aeration with Nitrification	1080	1080	1080	1035	1004	950
Sequencing Batch Reactors	1090	1090	1090	1047.5	1016	NA
Membrane Bioreactors	2700	2706	2706	2706	2706	NA

As processing needs become more stringent, the energy and O&M costs required to achieve water quality standards are increased compared to those listed above. EPRI reported that plants with biological treatment for nutrient removal and filtration use on the order of 30 to 50 percent more electricity for aeration, pumping, and solids processing than conventional activated sludge treatment (EPRI, 1994).

Figure 1 provides a comparison of observed electric energy intensity values based on plant flow rate for four different types of wastewater treatment facilities. Extrapolated from Figure 1, energy intensity values for small flows (< 0.1 MG) range from a low of ~ 2600 kWh/MG for trickling filters (i.e., fixed film) to a high of 3500 kWh/MG for Advanced Treatment (i.e., _______________).

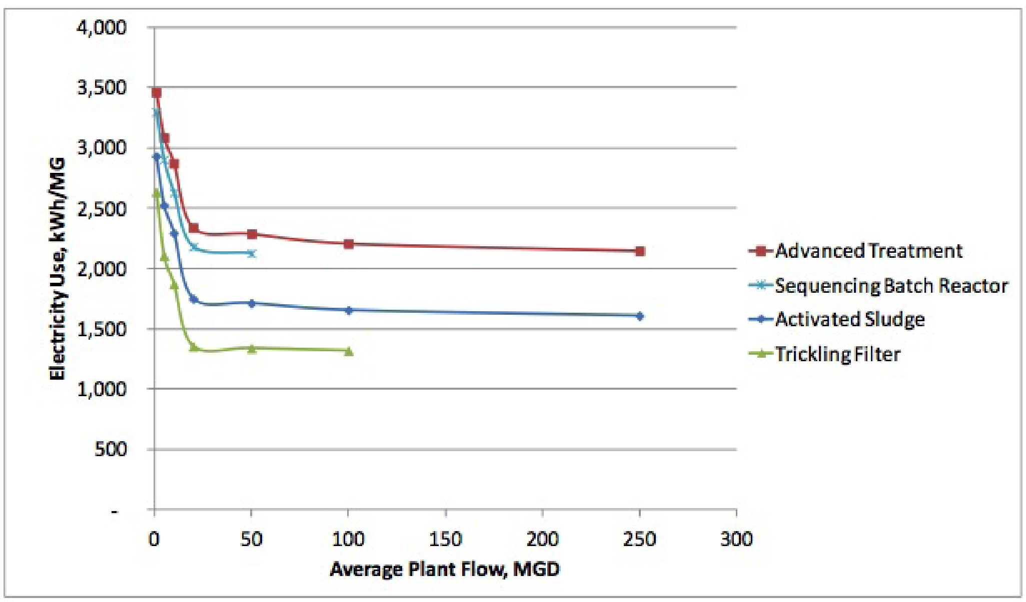

Figure 1. Electrical use for WWTP unit processes as a function of average plant flow (EPRI, 2013).

Systems with lower wastewater flows can even result in higher electrical usage costs than those reported. For example, an MBR facility (3,000 gpd) installed in 2008 serving a small commercial facility in Ohio has energy intensity values of around 79,000 kWh/MG. The system included a 5.5 Hp, 480 VAC, 3-phase (15 amp) blower. Energy associated with air delivery was 9,980 kW, resulting in **an annual electrical cost of $9,636/yr for only 3,000 gpd.**

Energy Conservation in Water and Wastewater Treatment Facilities (WEF MOP 32, 2009)

In 2009, the Water Environment Research Federation (WEF) published energy intensity values for various types and flow ranges of wastewater treatment unit processes. WEF suggests that energy intensity values for small treatment systems can be almost double energy intensity values for larger (> 1 MG) treatment facilities. Once more, WEF acknowledges the ability of fixed film processes to treat wastewater more energy efficiently than activated sludge facilities.

Table 4. Energy Intensity Values (kWh/MG) for Various WWTP Unit Processes (WEF MOP, 2009).

	Average Flow (MGD)					
Treatment Plant	1	5	10	20	50	100
Trickling Filter (Fixed Film)	1811	978	852	750	687	673
Activated Sludge	2236	1369	1203	1114	1051	1028
Advanced Treatment w/o Nitrification	2596	1573	1408	1303	1216	1188
Advanced Treatment w/Nitrification	2951	1926	1791	1676	1588	1588

The values provided in Table 4 are for the unit processes specified. Ancillary unit processes (primary clarification, secondary clarification, etc) are excluded.

Wastewater Engineering: Treatment and Resource Recovery (Metcalf & Eddy, 2014)

Metcalf & Eddy corroborates energy intensity values of fixed film processes versus activated sludge, again suggesting that electrical costs for activated sludge facilities with nitrification/denitrification can be three to four times higher than fixed film processes. Values listed in Table 5 are listed for all flow ranges and are listed per unit process, not complete WWTP values.

Table 5. Energy Intensity Values for Various WWTP Unit Processes (Metcalf & Eddy, 2014).

Technology	Energy Use (kWh/MG)
Trickling Filters (Fixed Film)	230 to 350
Activated Sludge for BOD Removal	530 to 4100
Activated Sludge w/Nitrification/Denitrification	870 to 880
Membrane Bioreactor	1900 to 3800
Return Sludge Pumping	30 to 50
Secondary Settling	13 to 15

Reliable Wastewater Treatment Can Be Energy-Efficient and Simple To Maintain (Richard Jex, 2014)

AdvanTex treatment systems, a fixed film secondary treatment process, are specifically designed to produce high quality, nitrified effluent for small wastewater flows. AdvanTex systems utilize fractional horsepower pumps that operate intermittently and only a fraction of the day, resulting in reduced energy usage compared to conventional activated sludge facilities. Table 6 reports theoretical energy intensity (kWh/MG) for AdvanTex treatment systems that include nutrient removal, as derived by Jex (2014).

Table 6. Energy Intensity Values for AdvanTex Treatment Systems, Theoretically Derived (Jex, 2014).

Unit Process	Average Flow (MGD)	
	0.025	0.05
AdvanTex WWTP (Fixed Film)	2170	1790

Small Community (0 to 1 MGD) Wastewater System Electrical Usage

Energy intensity unit values decrease with increasing flow, probably because of economy of scale and competent round-the-clock O&M. Small communities with small flows often lack the funding, experience and ability to properly run complex activated sludge treatment facilities. Small community treatment systems are generally operated on a part-time basis, often reactively, with infrequent adjustment and occasional, not continuous, laboratory control. Aeration controls are rarely optimized and are normally set to over-aerate well above energy efficiency thresholds. For example, having a dissolved oxygen concentration above 2 mg/L within the aeration tanks is a waste of energy.

As a result of operational inefficiencies and budget constraints, energy consumption in small WWTP is typically 30 to 40% higher, or more, compared to 15 to 30% of the operation and maintenance (O&M) budgets at large WWTPs. The affordability and compliance of a small wastewater

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treatment system requires a treatment facility with low electrical consumption and low biosolids production. Biosolids processing and aeration typically represent around 80% of the overall electrical usage in a typical activated sludge treatment facility, as shown in Figure 2.

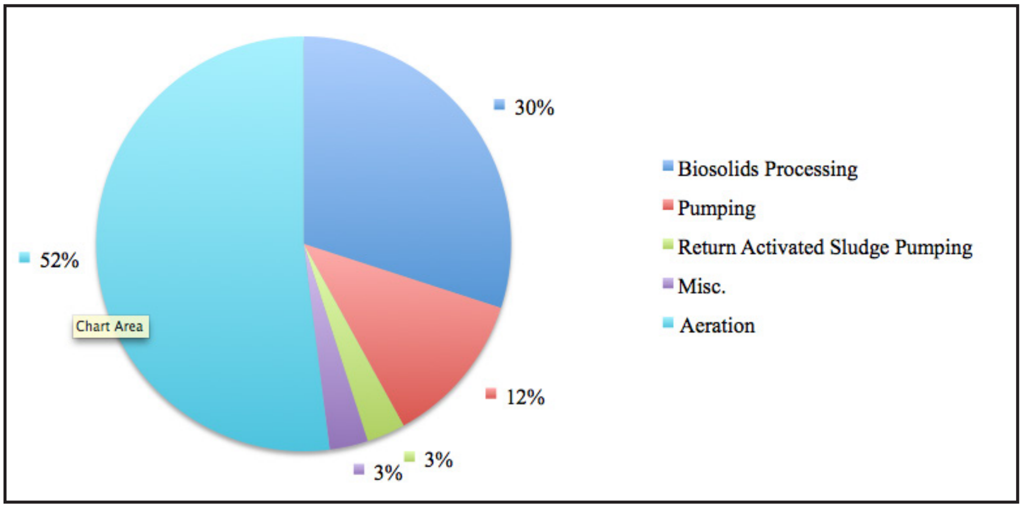

Figure 2. Typical energy end-uses in municipal wastewater treatment - activated sludge (Hazen & Sawyer).

Table 7 lists energy intensity unit values for activated sludge facilities with flows of 1 MGD or less. The average electrical usage is 5,931 kWh/MG (high of 7,288 kWh/MG), underscoring the inability of small communities to operate small activated sludge treatment facilities.

Table 7. Electrical Usage for Small (< 1 MGD) Activated Sludge WWTPs.

Unit Process	kWh/MG	Electrical Usage Data Source
Activated Sludge	5440	Water and Wastewater Energy Best Practices Guidebook
Aerated Lagoon	7288	Water and Wastewater Energy Best Practices Guidebook
Oxidation Ditch	6895	Water and Wastewater Energy Best Practices Guidebook
Activated Sludge	4100	Statewide Assessment of Energy Use By The Municipal W/WW Sector
Average	**5931**	

For comparison purposes, Table 7 only lists electrical usage values from complete wastewater treatment systems, not unit processes. In contrast, according to Richard Jex (2014), AdvanTex Treatment Systems (fixed film) have energy intensity values that range between 1,790 to 2,170 kWh/MG for small flows (< 1 MG).

Compared to the electrical usage data listed in Table 7, AdvanTex Treatment Systems can provide a reduction in electrical usage of up to 5,498 kWh/MG. On average, AdvanTex systems provide a deduction in electrical usage of more than 50% compared to activated sludge facilities. AdvanTex treatment systems are specifically designed to minimize biosolids production and electrical usage associated with wastewater aeration.

Electrical Usage Impact On User Charges

Small, unsewered communities typically require grant subsidies to achieve affordability levels for wastewater service. Therefore, any reductions in electrical usage at wastewater treatment facilities will not only lower user charges but potentially diminish state or federal grant contributions.

For instance, in 2014, the small community of Coffeeville, AL (200 connections), publicly bid an activated sludge MBBR WWTP (Q_a=35,000 gpd, Q_p=70,000 gpd) with subsurface dispersal for a total construction cost of $1,429,005. By means of a change order, post-bid, the community installed an AdvanTex WWTP (fixed film) at an adjusted bid of $1,465,000. The change order provided an increase in the contract price of $35,995, but a savings, relative to O&M (energy, biosolids management, and O&M labor) of ~ $6.57/month/household. **Based on the adjusted bid and the estimated O&M estimate (below), the AdvanTex option provided an estimated deduct in user charges of $5.71/month/household (30 yr, 4%) compared to the previously designed MBBR option.**

Table 8. Estimated Energy, Bio-Solids, and O&M Labor Costs for the AdvanTex and MBBR Treatment System in Coffeeville, AL.

Total Annual Operation & Maintenance Estimate	AdvanTex	MBR
Energy	$3,643	$8,722.27
Bio-Solids Management	$1,744	$6,606
O&M Labor	$5,850	$11,700.00
Total (Annual)	**$11,237**	**$27,028**
30 yr NPV (4% interest)	**$194,318**	**$467,373**

As shown in Table 3, fixed film treatment systems are specifically designed to reduce electrical demands relative to aeration and biosolids processing. For example, AdvanTex systems are operated at low hydraulic and organic loading rates, resulting in long solids retention times. The sludge production from a conventional activated sludge treatment facility with primary sedimentation is higher by a factor of 4.6 when compared with a septic tank system operated in conjunction with geotextile treatment process (assuming 0.15 kg/1000 L dry sludge from primary sedimentation, 0.084 kg/1000 L dry sludge from waste activated sludge, and 0.05 kg/1000 L dry sludge from septic tank solids, per Water Reuse, 2007).

Conclusion

Small communities have long struggled to provide wastewater solutions to their residents. Affordability is a huge barrier. Simple-to-operate, fixed film technologies are a good fit for small communities because they significantly reduce the costs of operational inefficiencies and electricity.

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